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(54) Abstract Title
Electrical contact of semi-conductive layer of HV cable

(57) An electrical conductor for high-voltage (10kV-800kV) windings comprises a central electrically conductive core and an outer semiconducting layer. A contacting device 20 comprising a resilient metallic spring member contacts the outer layer for grounding purposes. Alternatively, a single contacting device in the form of an elongate helical spring 40 may contact a plurality of turns of a wound conductor 10.

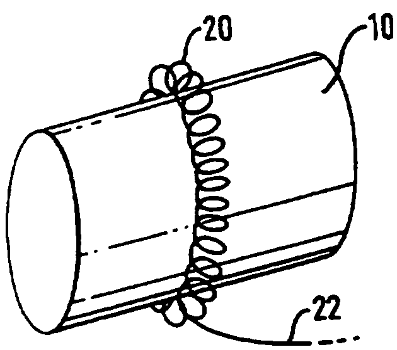

FIG.3.

FIG.6.

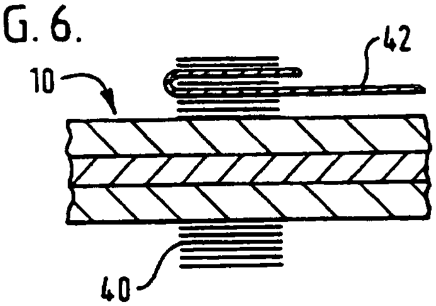

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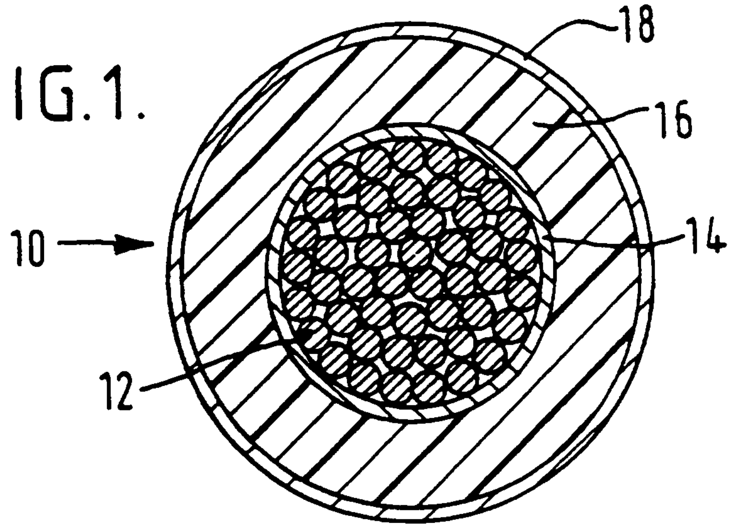
FIG.1.



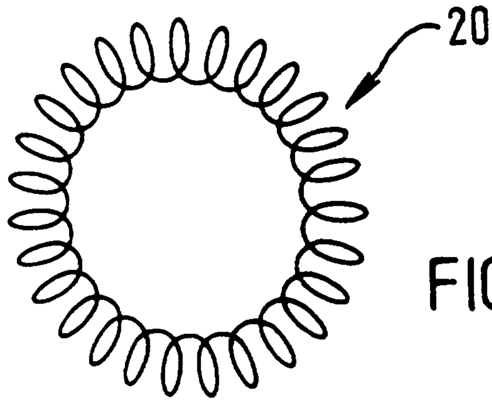


FIG.2.

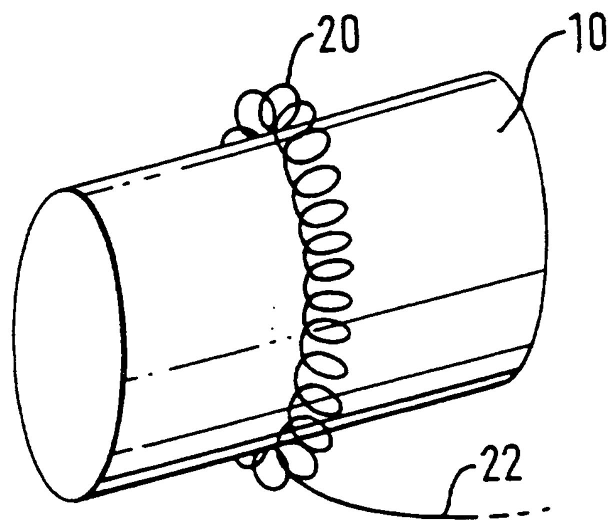
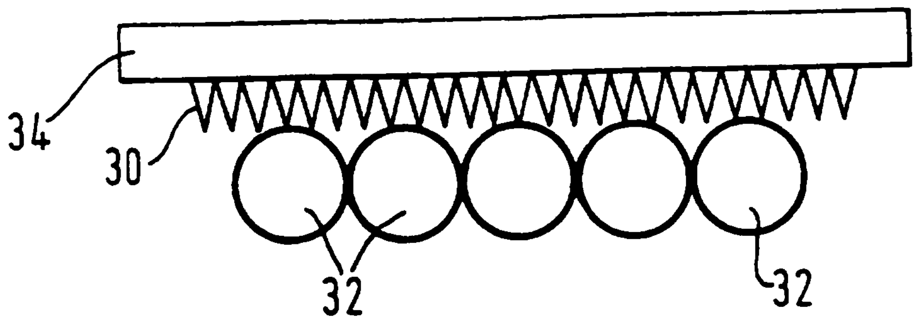


FIG.3.

FIG. 4.



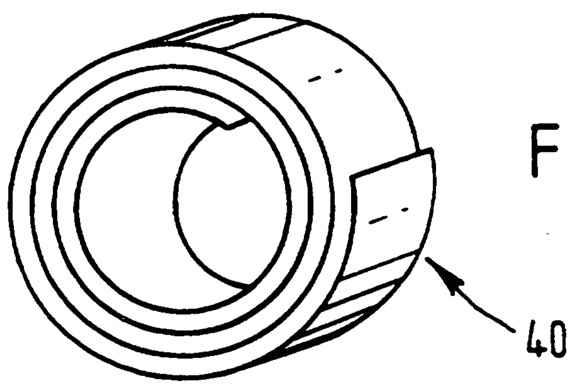
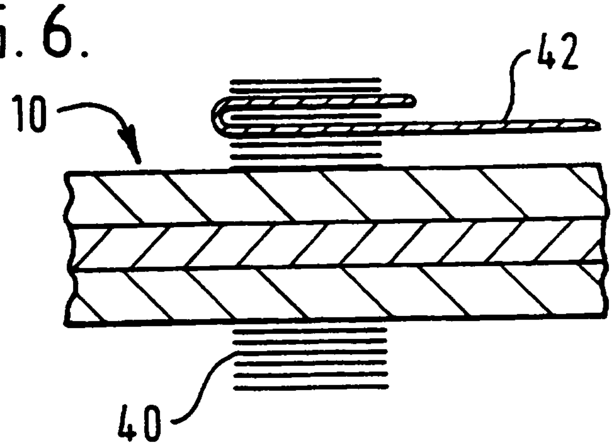


FIG. 5.

FIG. 6.



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INSULATED ELECTRICAL CONDUCTOR

The present invention relates to an insulated electrical conductor. More specifically, the invention relates to an insulated conductor, for use in high-voltage windings, having an outer layer of (at least semi-) conductive material which is contacted for grounding purposes. The conductor is intended to be used in large motors, generators and transformers at voltages in excess of 10 kV, in particular in excess of 36 kV, and preferably more than 72.5 kV up to very high transmission voltages, such as 400 kV to 800 kV or higher.

A particular conductor which can be used in the invention is shown in cross section in Figure 1. The conductor 10 comprises strands 12, for example of copper, the majority of which are insulated, surrounded by a first conductive layer 14. An insulating layer 16, for example of cross-linked polyethylene (XLPE), surrounds the first conductive layer 14 and is in turn surrounded by a second conductive layer 18.

Whilst the layers 14, 18 are described as "conductive" they are in practice formed from a base polymer mixed with carbon black or metallic particles and have a resistivity of between 1 and 10^5 Ωcm, preferably between 10 and 500 Ωcm. Suitable base polymers for the layers 14, 18 (and for the insulating layer 16) include ethylene vinyl acetate copolymer/nitrile rubber, butyl grafted polythene, ethylene butyl acrylate copolymer, ethylene ethyl acrylate copolymer, ethylene propene rubber, and polyethylenes of low density.

The first conductive layer 14 is rigidly connected to the insulating layer 16 over the entire interface therebetween. Similarly, the second conductive layer 18 is rigidly connected to the insulating layer 16 over the entire interface therebetween. The layers 14 - 16 form a solid

insulation system and are conveniently extruded together around the strands 12.

Whilst the conductivity of the first conductive layer 14 is lower than that of the electrically conductive strands 12, it is still sufficient to equalise the potential over its surface. Accordingly, the electric field is distributed uniformly around the circumference of the insulating layer 16 and the risk of localised field enhancement and partial discharge is minimized.

The potential at the second conductive layer 18, which should be zero or ground, is equalized at this value by the conductivity of the layer. At the same time, the conductive layer 18 has sufficient resistivity to enclose the electric field. In view of this resistivity, it is desirable to connect the conductive polymeric layer to ground at intervals therealong.

A problem experienced in making electrical contact with polymeric layers is that they expand in use, due to their high thermal expansion coefficient, and also creep under mechanical loading.

It is an object of the invention to maintain the second conductive layer substantially at ground by providing a suitable contacting device.

Accordingly, the present invention provides an electrical conductor for high-voltage windings, comprising central conductive means and an outer semiconductive layer, characterised in that at least one contacting device contacts the outer layer, the at least one contacting device comprising a resilient metallic spring member.

In a preferred embodiment, the central conductive means comprises one or more strands of wire, which are surrounded by an inner layer of lower conductivity than the wire, an

electrically insulating layer, and then by the outer layer which preferably has a higher conductivity than the insulating layer.

Preferably, the spring member is of a clad metal. The cladding may be of a noble metal such as silver, gold or platinum in order to resist corrosion. The clad metal may be any metal or alloy of suitable tensile strength.

In an embodiment of the invention, the spring member comprises a spiral spring surrounding the outer layer of one or more conductors, such that tension is exerted in the spring member to cause it to engage the outer layer. Conveniently, in this embodiment the spring member comprises an endless loop.

In an alternative embodiment, the spring member is elongated and urging means is provided for compressing the spring member against the outer layer.

Preferably, the outer layer of the conductor is made from a polymer mixed with carbon black. A plurality of contacting devices may be provided at intervals along the conductor for grounding purposes.

The contacting device of the invention provides a large contact area with the outer layer of the conductor and therefore avoids local heating of that layer. Because the device is resilient, the contact force between the device and the conductor is maintained throughout the lifetime of the conductor, despite thermal expansion and contraction of the conductor which occur due to ohmic losses, and the device is carried along if the outer layer creeps with respect to the central conductive means.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings, in which:-

Figure 1 is a cross-sectional view of a conductor according to the invention, but not showing the contacting device;

Figure 2 is a side view of a contacting device according to a first embodiment of the invention;

Figure 3 shows the contacting device of Figure 2 mounted on the conductor;

Figure 4 is a schematic sectional view of grounded conductors according to a second embodiment of the invention;

Figure 5 is a perspective view of a contacting device according to a third embodiment; and

Figure 6 shows the contacting device of Figure 5 mounted on a conductor.

Figure 2 shows a contacting device 20 in the form of an endless, generally circular, loop of helically twisted wire. In this embodiment, the device 20 is formed from a copper alloy which has been clad with silver.

Figure 3 shows the device 20 mounted on the conductor 10. The internal diameter of the contacting device 20 in its unstressed state is smaller than the external diameter of the conductor 10. Therefore when the contacting device 20 is placed around the conductor, it is tensioned such that it intimately contacts the outer layer 18 of the conductor at every turn of the helix. This ensures good electrical contact between the outer layer 18 and the contacting device 20. A grounding wire 22, one end of which is soldered or otherwise connected to the grounding device, has its other end connected to ground.

Figure 4 shows an alternative contacting device 30 in

the form of an elongated helical spring. This embodiment is suitable for grounding a number of turns 32 of a coiled conductor, for example in a rotating machine or transformer. The device 30 is pressed between a flat member 34, which may be a portion of a housing, and the conductor turns 32. The device 30 is conveniently formed from silver-clad copper - beryllium alloy.

Figure 5 shows another alternative contacting device 40 in the form of a "watch-spring". The contacting device 40 has an internal diameter in its unstressed state which is smaller than the external diameter of the conductor 10.

Figure 6 shows the device 40 mounted on the conductor 10, which can be achieved either by wrapping the device 40 around the conductor or placing it over the end of the conductor. In order to improve electrical contact between the device 40 and the outer layer 18, the latter should be painted with silver paint prior to the addition of the contacting device 40. A grounding wire 42 is folded between two adjacent turns of the contacting device 40 in a particularly convenient manner. This embodiment of the contacting device takes up little space and can be placed on the conductor (which may be a superconductor) independently of other design elements.

The electrical insulation of an electrical conductor according to the invention is intended to be able to handle very high voltages, e.g. up tp 800 kV or higher, and the consequent electric and thermal loads which may arise at these voltages. By way of example, electrical conductors according to the invention may comprise windings of power transformers having rated powers from a few hundred kVA up to more than 1000 MVA and with rated voltages from 3 - 4 kV up to very high transmission voltages of from 400 - 800 kV or more. At high operating voltages, partial discharges, or PD, constitute a serious problem for known insulation systems. If cavities or pores are present in the

insulation, internal corona discharge may arise whereby the insulating material is gradually degraded eventually leading to breakdown of the insulation. The electric load on the electrical insulation in use of an electrical conductor according to the present invention is reduced by ensuring that the inner layer of (semi)conductive material of the insulation system is at substantially the same electric potential as conductors of the central electrically conductive means which it surrounds and the (semi)conductive outer layer is at a controlled, e.g. earth, potential. Thus the electric field in the electrically insulating layer between these inner and outer layers is distributed substantially uniformly over the thickness of the intermediate layer. By having materials with similar thermal properties and with few defects in these layers of the insulation system, the possibility of PD is reduced at given operating voltages. The electrical conductor can thus be designed to withstand very high operating voltages, typically up to 800 kV or higher.

CLAIMS

1. An electrical conductor for high-voltage windings, comprising central electrically conductive means and an outer semiconductive layer, characterised in that at least one contacting device contacts the outer layer, the at least one contacting device comprising a resilient metallic spring member.

2. An electrical conductor according to claim 1, wherein the central conductive means comprises one or more strands of wire, which are surrounded in turn by an inner layer of lower conductivity than the wire, an electrically insulating layer, and then by the outer layer.

3. An electrical conductor according to claim 1 or 2, wherein the outer layer is polymeric, includes carbon black and has an electric resistivity of between 1 and 10^5 Ωcm.

4. A conductor according to claim 3, wherein the resistivity of the outer polymeric layer is between 10 and 500 Ωcm.

5. A conductor according to claim 1, 2, 3 or 4, wherein the spring member surrounds the outer layer of the conductor such that tension is exerted in the spring member to cause it to engage the outer layer.

6. A conductor according to any one of the preceding claims, wherein the conductor is wound in a plurality of turns and the metallic member is urged into contact with said turns.

7. A conductor according to any of the preceding claims, wherein the spring member comprises a spiral spring.

8. A conductor according to claim 7, wherein the

spring member is in the form of a watch-spring.

9. A conductor according to claim 8, wherein a grounding wire is folded between at least two turns of the watch-spring.

10. A conductor according to any one of claims 1 to 7, wherein the spring member forms an endless loop.

11. A conductor according to any one of the preceding claims, comprising a plurality of contacting devices spaced at intervals therealong.

12. A conductor according to any one of the preceding claims, wherein the or each spring member is of a clad metal.

13. A conductor according to claim 12, wherein the cladding is of silver, gold or platinum.

14. A conductor according to claim 12 or 13, wherein the clad metal is copper or a copper alloy.

15. A conductor according to any one of the preceding claims, characterised in that the electrically conductive means and outer semiconductive layer are designed for high voltage, suitably in excess of 10 kV, in particular in excess of 36 kV, and preferably more than 72.5 kV up to very high transmission voltages, such as 400 kV to 800 kV or higher.

16. A conductor according to any one of the preceding claims, characterised in that the electrically conductive means and outer semiconductive layer are designed for a power range in excess of 0.5 MVA, preferably in excess of 30 MVA and up to 1000 MVA.

The Patent Office

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Application No: GB 9725322.3
Claims searched: 1 to 16

Examiner: Mr F J Fee
Date of search: 25 June 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H2E [EDGX, EEGKR, EEMX, EFAX, EFBA, EFBX, EFCX, E972, E974]

Int Cl (Ed.6): H01R, H02G

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	None	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		